UPPER EXTREMITY INJURIES IN ROAD TRAFFIC ACCIDENTS

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Paper number 07-0239

ABSTRACT

The purpose of this study was to obtain more specific information on upper limb injuries sustained by front seat occupants in car accidents with a view to identifying injuries that are a priority for prevention and further research.

After identification of cases from the Vehicle Safety Research Centre (VSRC) through the Transport Research Laboratory (TRL) the appropriate hospital records and radiographs were reviewed. Data were analysed to identify the frequency and severity of upper limb injuries, the mechanism of injury and the impairment sustained in accordance with the American Medical Association guides [1]. The NHS financial costs of management for the upper limb injury and that for the patient in total were calculated.

Sixty two cases were reviewed (34 male), aged 18-83 years (mean 44 years). There were 20 clavicle fractures, 18 elbow and forearm fractures, 16 shoulder and arm injuries, and 26 wrist and hand injuries.

The median upper limb Abbreviated Injury Score was 2 and the overall Injury Severity Score ranged from 4 to 50 (median 6). In terms of impairment, the upper extremity sensory deficit ranged from 0 to 9% and motor deficit 0 to 22.5% giving up to 5% sensory and 13.5% motor "whole person impairment".

The mean estimated treatment cost for upper limb management was calculated at £2,200 compared with a total injury treatment cost of a mean £11,000 per person.

Limitations of the study include its retrospective nature and possible selection bias.

The study has identified the range and costs (impairment and financial) of upper limb injuries in road traffic accidents. These data will be used by researchers to both improve the current car crash dummies in the upper limb and to allow accurate finite element remodelling. Legislative changes to car requirements for upper limb safety may be brought forward in the longer term.

INTRODUCTION

With the introduction of seat-belt legislation into the UK in 1983 there has been a significant reduction in head and chest injuries but no reduction in lower limb injuries in road traffic accidents [2]. Upper limb injuries in road traffic accidents have been less extensively investigated than is the case with lower limb and visceral injuries and as a result are poorly understood.

There has been an increasing concern that upper limb injuries might be becoming more common but accident analyses have varying conclusions in this area. Upper limb injuries might occur as a result of the acceleration/deceleration forces of the accident resulting in the limb being subjected to injury as a consequence of its momentum or because of the efforts of the occupant to restrain themselves with their upper limbs at the time of the accident. More recently, the possibility has been raised, that the front or side air-bags might also contribute to upper limb injury [3, 4].

The aim of the project was to obtain more specific information on upper extremity injuries sustained by front seat occupants in road traffic accidents, whilst wearing seat-belts and experiencing frontal collisions. The aim was to identify injuries that are a priority for prevention and to help direct further research.

Upper limb injuries have the potential to cause high levels of functional impairment and as a result may have significant unforeseen wider economic costs. This study was designed to specifically evaluate the functional impairment produced as a result of common upper limb RTA injuries.

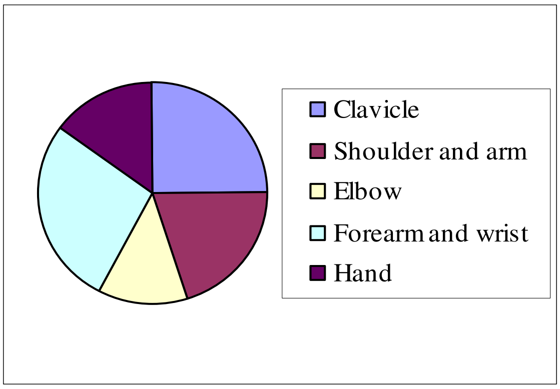
METHODS

Ethical approval was obtained for this study (Nottingham Research Ethics Committee ref: 04/Q2403/119). Cases were identified through the UK car crash injury data-base by the Vehicle safety research centre (VSRC) in Loughborough and the Transport Research Laboratory (TRL) in Berkshire. Patients were included if they had been recorded on the database as having sustained an upper limb injury as a seat-belted front seat passenger in a road traffic accident and had further been treated at the Nottingham University Hospitals NHS Trust. Only frontal impact collisions with no rollover were included. Patients sustaining only minor abrasions and contusions were excluded and only AIS 2+ upper extremity injuries were investigated. Hospital records and radiographs were reviewed. These data were analysed to summarise the injuries sustained and to classify them according to their frequency, severity and subsequent impairment using the American Medical Association (AMA) guidelines on the "Evaluation of Permanent Impairment" [1]. The medical researchers comprised two consultant orthopaedic and trauma surgeons and one specialist registrar (senior intern). An initial opinion was formed by consensus between one of the consultants and specialist registrar and in cases where there was a significant difference of opinion a final opinion was given by the senior consultant surgeon. The cost related to upper limb injuries and total cost of care for the injured parties were estimated using standard recognised National Health Service, UK Government, costing methods.

RESULTS

Sixty two appropriate cases (34 male), aged 18-83 years (mean 44 years) identified from the Co-operative Crash Injury Study (CCIS) database were recommended by the TRL team for investigation and these cases were reviewed by the clinicians. Medical records were found for all cases referred by the VSRC with no cases being lost to the study. The location of the upper extremity injuries are shown in Figure 1.

Figure 1. Location of AIS 2+ upper extremity injury in front seat occupants in frontal collisions.



There was a total 20 clavicle fractures of which 19 were sustained by the driver of the vehicle and 18 were right sided. 19 of the 20 occurred in the limb closest to the door (outboard limb). The majority occurred in the region of the middle third of the clavicle (80%) (Table 1).

Table 1. Location of fracture of clavicle in front seat occupants in frontal collisions

Location of fracture of clavicle	Frequency
Medial	1
Middle third	16
Middle/lateral third	1
Lateral	2

The commonest mechanism was identified as three point loading from the seatbelt (Table 2).

Table 2. The suggested mechanisms of AIS 2+ upper extremity injuries in front seat occupants in frontal collisions

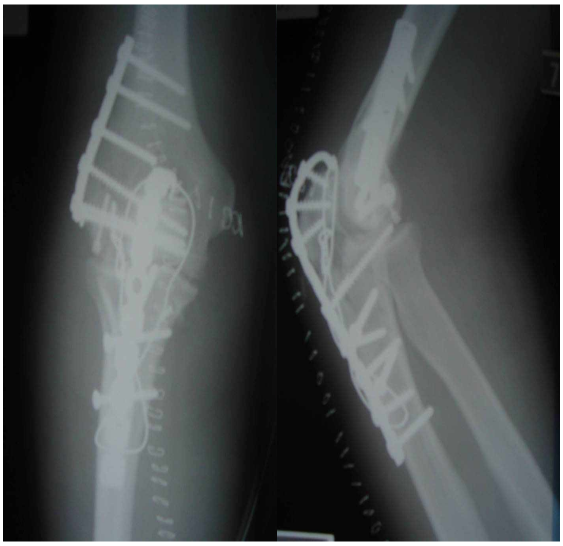
Injury location	Type of mechanism	Frequency	Total number
Clavicle	3-point seatbelt loading	15	20
	Lateral compression	3	
	Indirect force	1	
	Airbag to sternum	1	
Shoulder or arm	Whiplash/seatbelt contusion	5	16
	Axial force	3	
	High energy torque force	2	
	Lateral compression	2	
	Flail arm with inertial force	2	
	High energy 3-point bending	1	
	Direct contact A-frame	1	
Elbow	Direct trauma/intrusion	7	10
	Axial load	2	
	Indirect torque force arm	1	
Forearm	Pin-point loading	3	8
	Direct contact-Intrusion into driver space	2	
	Direct contact-Steering wheel	1	
	Multiple point contact	1	
	3-point loading ulna	1	
Wrist	Forced hyper-extension	11	14
	Direct impact/intrusion	3	
Hand	Direct impact/intrusion	5	12
	Flail arm	2	
	High torque force finger	1	
	Hyperflexion finger	1	
	Forced extension of thumb	2	
	Forced flexion of extended thumb	1	

Three of the clavicle fractures resulted in a non-union, two of which subsequently required remedial surgery - operative fixation (Figure 2).

Figure 2. One of the clavicle fractures treated with surgical plating after developing a non-union.

A further case with a fracture at the lateral end of the clavicle is currently awaiting operative intervention with an acromio-clavicular joint reconstruction. There were 3 acromio-clavicular dislocations and 1 shoulder dislocation. The forearm sustained significant trauma in this series, involving 8 fracture dislocations of elbow, 4 of which were open injuries. There were 3 open fractures of the forearm, 1 open fracture of the wrist and 1 dislocation of the wrist joint.
The full data and summary is presented in Table 3. The Injury Severity Score (ISS) ranged from 4 to 50 with a median of 6. The Upper Limb Abbreviated Injury Score ranged from 2 to 4 with a median of 2.

Figure 3. A severe fracture of the humerus, radius and ulna just around the elbow required reconstruction with plates and screws.



Upper extremity sensory deficits ranged from 0 to 9% and motor deficits 0 to 22.5% giving up to 5% sensory and 13.5% motor "whole person impairment".
The mean cost of the medical management of the upper limb injuries in these subjects was £2415 (£5 to £9951). The mean total injury treatment cost of the same group of subjects was £10,883 per person as a consequence of other injuries sustained in the same accident.

Table 3. Severity, financial cost and functional impairment of upper extremity injuries to front seat occupants in frontal crashes

Injury location	Inboard limb	Outboard limb	Total	ISS median (range)	AIS median (range)	Mean Cost of upper limb injury (£)	Mean Cost of other injuries (£)	Mean Total cost (£)	Average Upper limb impairment (%)	Whole person impairment (%)
Clavicle	19	1	20	12 (4 -50)	2 (2-4)	2,431	13,545	15,976	1.5	0.9
Shoulder or arm	10	6	16	2 (4-29)	2 (2-4)	1,853	4,877	6,730	2.7	1.6
Elbow	7	3	10	16 (5-29)	3 (2-4)	5,710	14,943	20,653	4.7	3.0
Forearm	5	3	8	16 (4-38)	2.5 (2-3)	4,218	19,489	23,707	0.3	0.3
Wrist	9	5	14	14 (4-24)	2 (2-4)	4,184	9,046	13,230	3.8	2.3
Hand	8	4	12	2 (4-34)	2 (2-3)	1,844	5,330	7,174	1.3	0.8

DISCUSSION

This study highlights the significance of upper limb injuries in road traffic accidents. There was a surprisingly high incidence of clavicle fractures, often the result of three-point seatbelt loading. The number of these injuries, their consequence and the costs of their treatment had not been recognised previously. The medical researchers have raised the possibility that the frequency of these injuries may be increased compared with the past and may relate to advances in car safety and thus resultant morbidity, as opposed to mortality, as more people survive such accidents. Changes in seatbelt design and tensioning may also be a co-factor.

Many clavicle fractures are discharged from primary care prior to healing and therefore impairment may be under-estimated as it is often assumed that they will make a full recovery. A prospective study with adequate follow up is required to establish a more accurate analysis of the degree of impairment sustained.

In these frontal crashes, the outboard limb most frequently sustained AIS 2+ injuries. The outboard limb lies adjacent to the stiff structures of the door, A-pillar and window and is vulnerable to injury from flailing as well as contact from facia/side wall intrusion. 80% of clavicle fractures were attributed to the seatbelt loading from the diagonal section of the seat belt. The shoulder injuries were identified as lateral compression or axial compression sources. Two thirds of the elbow injuries, including the most devastating, were identified as direct point loading, commonly associated with intrusion. There were 8 fracture dislocations/Monteggia fractures of the elbow, including 4 open injuries. This group had a poor functional outcome with an average upper extremity and whole person impairment of 4.8% and 7.8% respectively. The majority (75%) occurred in the outbound limb from direct trauma. The average cost of the upper extremity injuries in these patients was £26,350.

Two thirds of the forearm fractures occurred via 3 point loading, most commonly in the outboard limb, most likely due to flail arm into the side door structure and A-pillar. Wrist injuries were frequently of a hyperextension pattern, most likely from steering wheel or airbag contact.

Hand and wrist injuries have previously been shown to be rare in rollover and side-struck impacts, and relatively common in frontal crashes [5], prompting suggestion that air-bags might significantly contribute to upper limb injury. The majority of hand and wrist injuries in this study of AIS 2+ also occurred in the outboard limb. If these injuries do not result directly from airbag deployment, they may occur as a secondary effect of being forced into the hard side structures.

The cost analysis which was carried out included 1) the length of hospital stay; 2) the cost of medical investigations; 3) the cost of the treatment carried out including surgery and physiotherapy as well as; 4) the cost of outpatient follow up. The single largest cost was inpatient stay on the Intensive care unit (ITU), High dependency unit or on the ward. As most upper limb injuries do not require ITU care and often only require a minimal inpatient ward stay, the cost to the secondary care unit is thus comparatively small. However the cost to society and to the individual is considerably greater and this has not been fully assessed in this study, although an indication of impairment has been ascertained. It is important to emphasise that a patient with a clavicle fracture is unable to drive and rarely returns to work inside 8 weeks, partly as a consequence of being unable to drive. As 84% of the study population were within the working age range this could have significant effects during the weeks or months required for recovery.

CONCLUSION

The study has demonstrated the significance of upper limb injuries in road traffic accidents both from their functional outcome and their cost. We would recommend further investigation into the high incidence of clavicle fractures and into seatbelt design. A better understanding of the prevalence and implications of these injuries should be obtained via a large prospective, multi-centre study.

RECOMMENDATIONS

The major limitations of this retrospective study are the selection procedure and sample bias and whether the findings are truly representative. To evaluate these further, a prospective study would be required in the form of a multi-centre observational study.

ACKNOWLEDGEMENTS

We are grateful to the Vehicle safety research centre (VSRC), Loughborough and the Transport Research Laboratory (TRL), Berkshire for identification and selection of cases for this study.

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